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Novick

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(54) **METHOD AND APPARATUS FOR GUARANTEEING A MINIMUM CELL RATE (MCR) FOR ASYNCHRONOUS TRANSFER MODE (ATM) TRAFFIC QUEUES**

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(58) **Field of Search** 370/230, 230.1, 370/232–234, 235, 235.1, 236, 395.1, 395.4, 395.41, 395.42, 395.43, 395.61, 412, 413, 414, 418, 468

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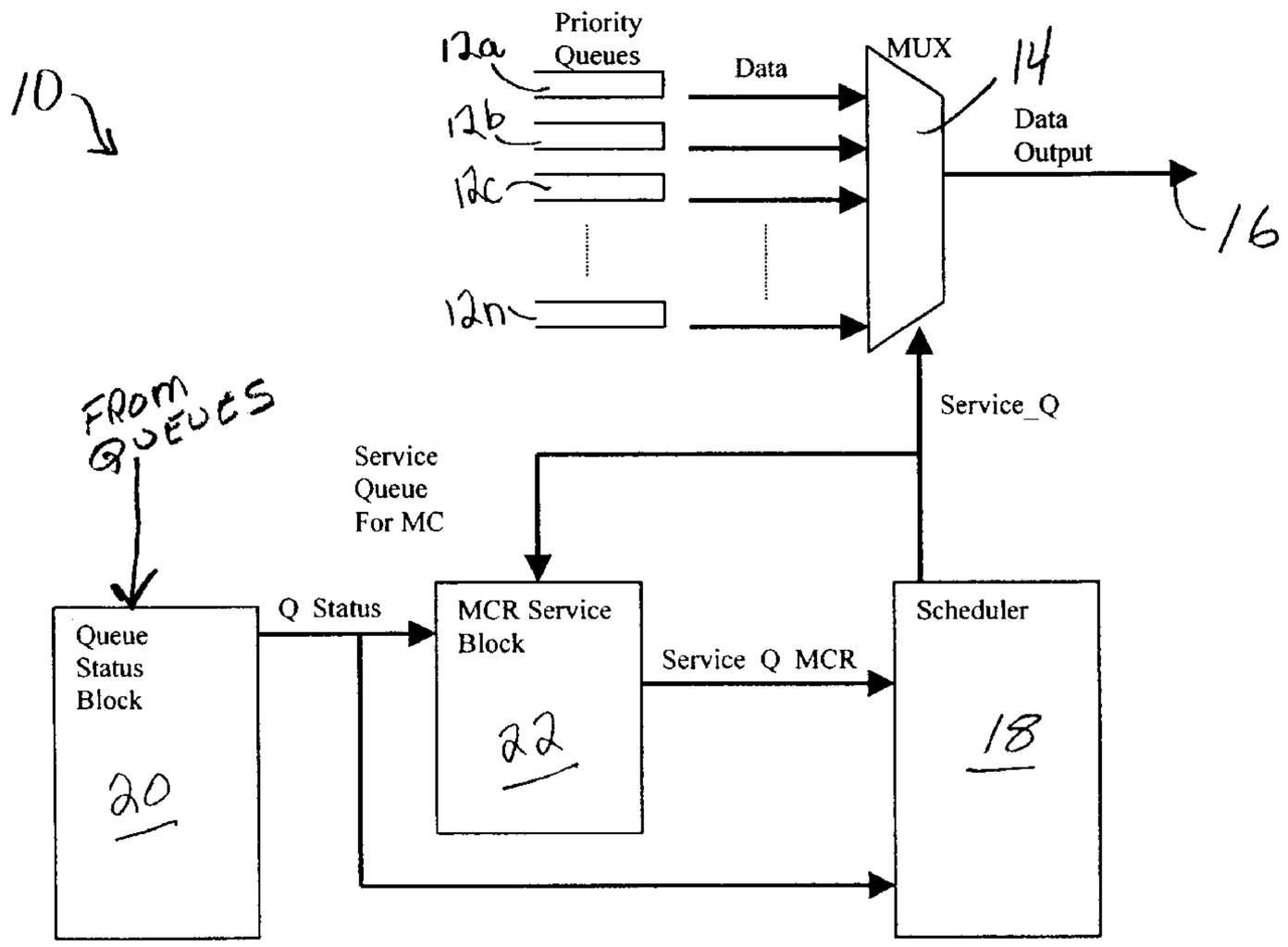
(57) **ABSTRACT**

An apparatus for guaranteeing MCR in an ATM device includes at least one queue for each service category, a scheduler for dequeuing cells from the queues, a queue status block for indicating which queues are empty, and an MCR service block. The MCR service block includes a plurality of timers, at least one for each service category. According to the methods of the invention, an MCR value is selected for each queue (or service category) and a timer in the MCR service block is set according to the MCR value. The scheduler dequeues cells in strict priority from non-empty queues as determined by the queue status block. The scheduler is preempted, however, by the MCR service block when a queue fails to be serviced before its associated timer expires. The arrangement of queues and associated timers is subject to alternate embodiments.

16 Claims, 3 Drawing Sheets



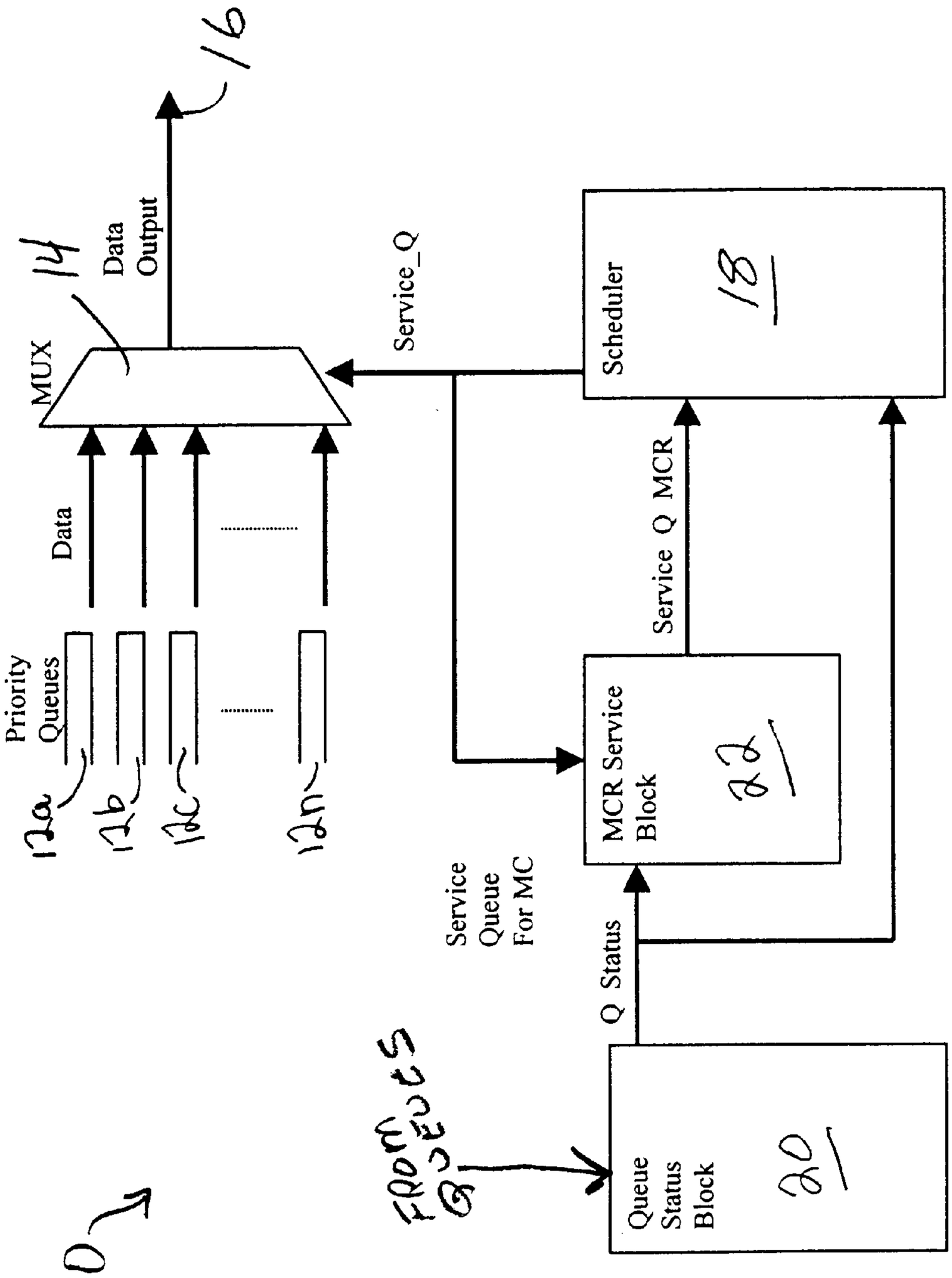

16
Data Output
14
MUX
Service_Q
Scheduler
18
Priority Queues
Data
12a
12b
12c
12n
Service Q MCR
Service Queue For MC
MCR Service Block
22
Q Status
Queue Status Block
20
FROM QUEUES
10

FIG. 1

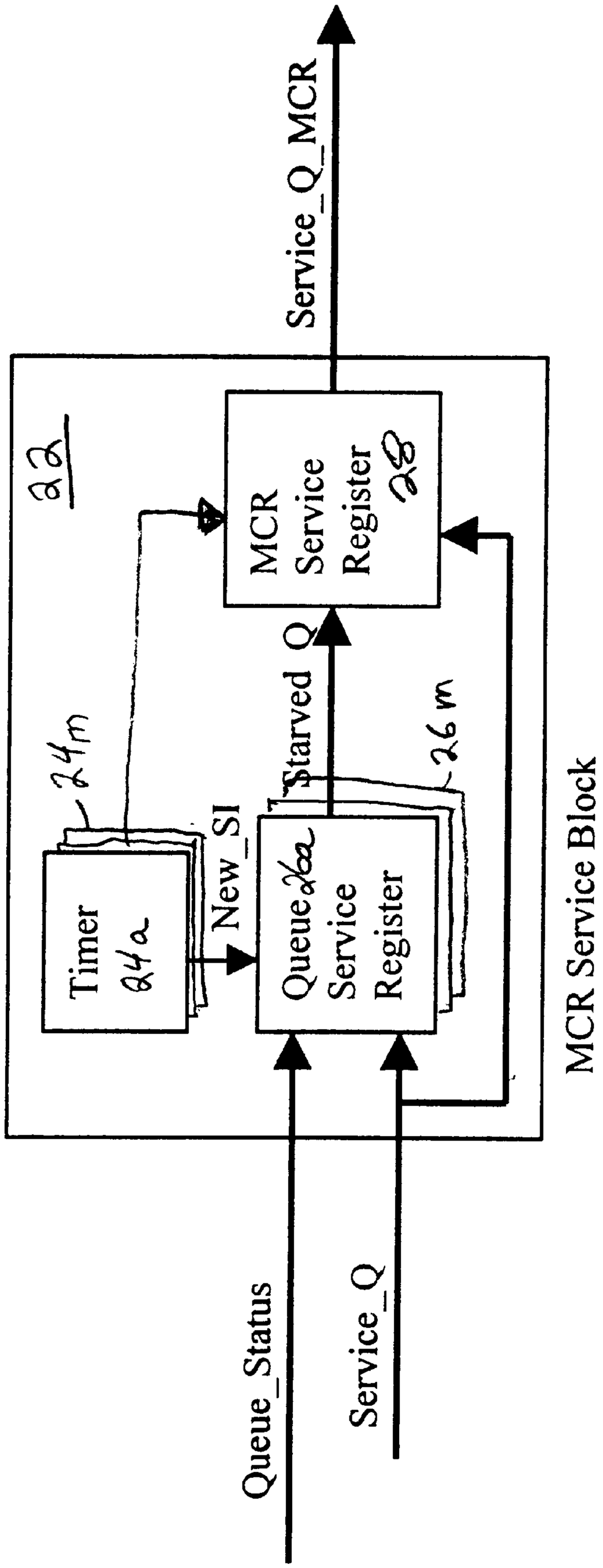

Service_Q_MCR
22
MCR Service Register 28
Starved Q
24m
26m
New_SI
Timer 24a
Queue 26a Service Register
MCR Service Block
Queue_Status
Service_Q

FIG. 2

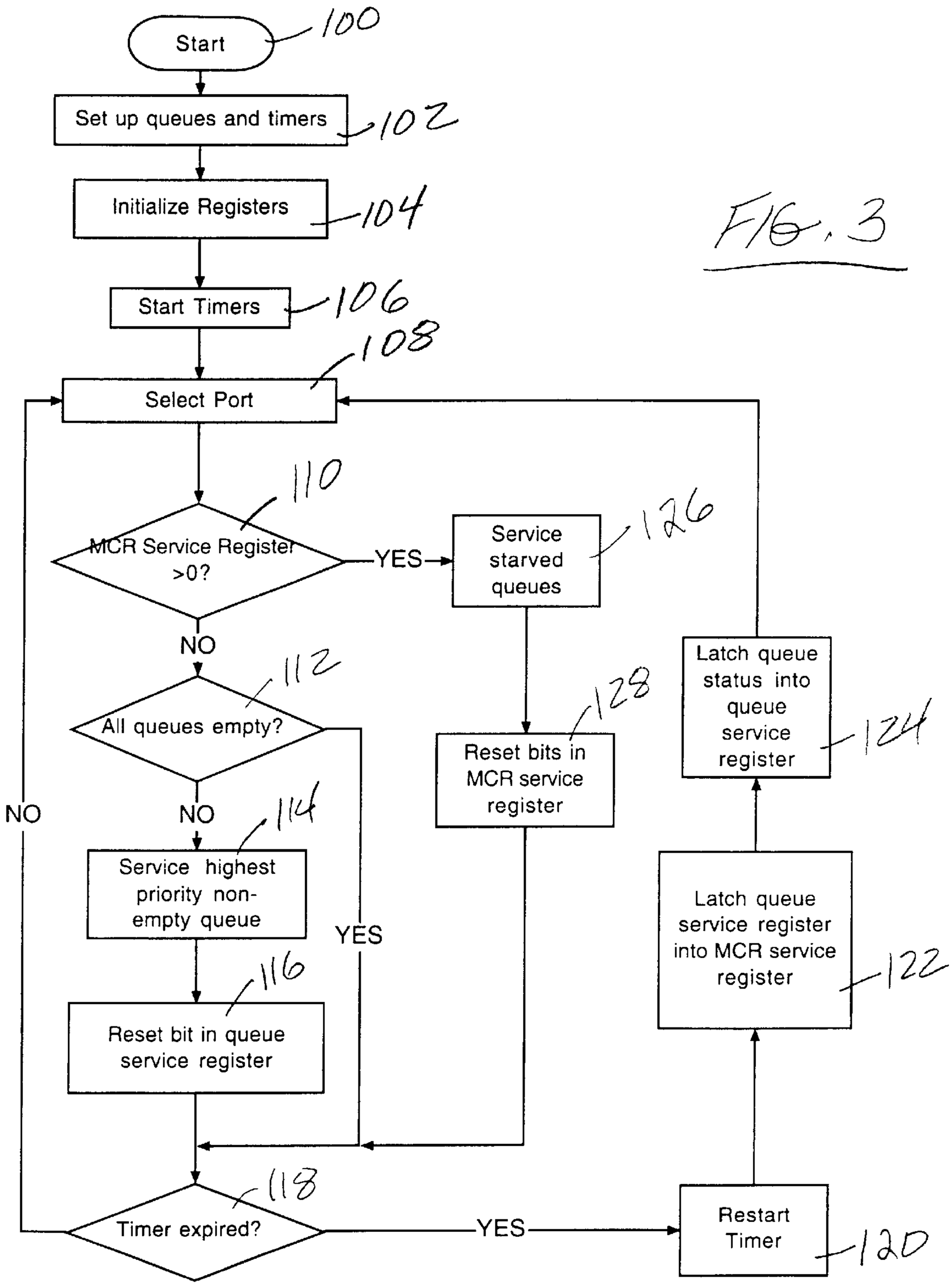

Start
100
Set up queues and timers
102
Initialize Registers
104
Start Timers
106
Select Port
108
MCR Service Register >0?
110
YES
Service starved queues
126
NO
All queues empty?
112
NO
NO
Service highest priority non-empty queue
114
YES
Reset bits in MCR service register
128
Latch queue status into queue service register
124
Latch queue service register into MCR service register
122
Reset bit in queue service register
116
Timer expired?
118
YES
Restart Timer
120

FIG. 3

METHOD AND APPARATUS FOR GUARANTEEING A MINIMUM CELL RATE (MCR) FOR ASYNCHRONOUS TRANSFER MODE (ATM) TRAFFIC QUEUES

BRIEF DESCRIPTION OF THE APPENDIX

The enclosed CD-ROM appendix is incorporated herein by to reference. The CD-ROM is in ISO 9660 Macintosh® format and includes the following Adobe® Acrobat® files:

List of files	Size (Bytes)	Date of Creation
SCB_FR.pdf	252,958	Apr. 12, 2002

The file SCB_FR.pdf is a document entitled "Aspen Express Scheduler Block (SCB) Requirements Specification" which illustrates in detail a presently preferred embodiment of the invention.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to the allocation of bandwidth in an ATM (Asynchronous Transfer Mode) network. More particularly, the invention relates to methods and apparatus for guaranteeing a minimum cell rate (MCR) or a sustained cell rate (SCR) in ATM traffic queues.

2. State of the Art

Perhaps the most awaited, and now fastest growing technology in the field of telecommunications is known as Asynchronous Transfer Mode (ATM) technology. ATM was designed to be a carrier of integrated traffic, e.g. voice, data, and video. ATM utilizes fixed length packets (called "cells") of 53 octets (5 octets header and 48 octets payload). Current ATM service is offered in different categories according to a user's needs. These categories include, in order of priority: constant bit rate (iCBR), variable bit rate-real time (VBR or VBR-rt), variable bit rate-non-real time (VBR-nrt), guaranteed frame rate (GFR), available bit rate (ABR), unspecified bit rate plus (UBR+), and unspecified bit rate (UBR). CBR and VBR-rt are "real-time" categories suitable for streaming video and voice connections. These categories are given the highest priority in the ATM network. The other five categories are considered "non-real-time". For GFR, ABR, and UBR+, users pay for a minimum cell rate (or guaranteed frame rate) which is an average rate taken over time during which there may be bursts up to a specified peak cell rate (PCR). For convenience, these three categories are referred to as MCR (minimum cell rate) services. According to ATM Forum standards, both VBR-rt and VBR-nrt require a "sustained cell rate" (SCR) which is substantially the same requirement as MCR. For UBR, no minimum bandwidth is guaranteed. UBR connections are serviced last if there is any available bandwidth after servicing all of the higher categories of service. UBR, is referred to as "best effort" service. Service categories and traffic management issues are specified in the ATM Traffic Management Specification Version 4.1, AF-TM-0121.000, March 1999.

ATM traffic management systems vary in complexity and cost. The simplest method of managing traffic is strict priority queuing. According to strict priority queuing, each traffic flow (virtual circuit or virtual path) is assigned a service category bulk queue. These queues are then serviced in strict priority order. The more complex systems assign a

separate queue to each traffic flow and shapes each one according to a specific traffic contract so that it meets a required SCR or MCR and does not exceed a PCR (peak cell rate) and limits the cell delay variation (burstiness).

The strict priority mechanism is quite simple and inexpensive to implement but provides only minimum quality of service (QOS) since there are no individual guarantees for each traffic flow. Also, the lowest categories of service are subject to starvation with no guarantee of any service at all. The shaping mechanisms provide all the necessary guarantees for individual traffic flows but shaping mechanisms are very complex and costly to develop.

SUMMCRY OF THE INVENTION

It is therefore an object of the invention to provide methods and apparatus for guaranteeing MCR or SCR in ATM traffic queues.

It is also an object of the invention to provide methods and apparatus for guaranteeing MCR or SCR in ATM traffic queues which guarantees MCR or SCR in each traffic flow of an ATM device.

It is another object of the invention to provide methods and apparatus for guaranteeing MCR or SCR in ATM traffic queues which prevents starvation of lower service categories.

It is a further object of the invention to provide methods and apparatus for guaranteeing MCR or SCR in ATM traffic queues which are relatively simple and inexpensive to implement as compared to known traffic shaping systems.

In accord with these objects which will be discussed in detail below, the apparatus of the present invention includes at least one queue for each service category, a scheduler for dequeuing cells from the queues, a queue status block for indicating which queues are empty, and an MCR service block. The MCR service block includes a plurality of timers, at least one for each service category. According to the methods of the invention, an MCR value is selected for each queue (or service category) and a timer in the MCR service block is set according to the MCR value. The scheduler dequeues cells in strict priority from non-empty queues as determined by the queue status block until a timer expires. When a timer expires, it is determined whether any queues associated with the timer failed to receive service during the timer interval. If such "starved queues" exist, the scheduler is preempted by the MCR service block so that the starved queues receive service. The arrangement of queues and associated timers is subject to alternate embodiments. As stated above, at least one queue is provided for each service category. However, according to an alternate embodiment, separate queues for each traffic flow are implemented. According to still another embodiment, multiple queues are implemented for some service categories, e.g. three separate priority queues for UBR service so that different classes of IP traffic can be mapped into UBR traffic. As stated above, at least one timer is provided for each service category. When a timer expires, the scheduler is directed to service all of the unserviced queues in the associated service category. According to an alternate embodiment, a separate timer is associated with each queue. The invention may be implemented in either a single port or multi-port device.

Additional objects and advantages of the invention will become apparent to those skilled in the art upon reference to the detailed description taken in conjunction with the provided figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified block diagram of an apparatus according to the invention;

FIG. **2** is a simplified block diagram of the MCR Service Block of FIG. **1**; and

FIG. **3** is a simplified flowchart illustrating the methods of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, an apparatus **10** according to the invention includes a plurality of queues **12***a*, **12***b*, **12***c*, . . . , **12***n*, feeding to a multiplexer **14** having a single port output **16**. Although not shown in FIG. **1**, an apparatus according to the invention could have multiple output ports and the methods described below takes into consideration multiple ports. A scheduler **18** controls the dequeuing of cells from the queues **12***a*, **12***b*, **12***c*, . . . , **12***n* by controlling the multiplexer **14**. A queue status block **20** receives status information from the queues **12***a*, **12***b*, **12***c*, . . . , **12***n* and provides status information to the scheduler **18**. The queue status block is preferably an n-bit word or vector where n is the number of queues. Each bit indicates whether the associated queue is empty (e.g. 0=empty, 1=not empty). The scheduler **18** reads the queue status block **20** when servicing the queues **12***a*, **12***b*, **12***c*, . . . , **12***n*, and ignores the empty queues. The number of queues is at least equal to the number of service categories supported by the apparatus **10**. With the minimum number of queues, all traffic flows in the same service category share the same queue. Alternatively, separate queues may be provided for each traffic flow or some service categories may be provided with a single queue while others are provided with multiple queues. An example of an implementation in which multiple queues are set up for a single service category is when mapping different classes of IP service into UBR traffic. In any event, according to the methods of the invention, an MCR or SCR is associated with each queue requiring such and all of the queues in the same service category are associated with the same MCR or SCR.

According to the presently preferred embodiment the MCR or SCR is expressed as a number of clock ticks during which at least one cell must be sent from this queue. For example, if a minimum cell rate (MCR) of 1,000/sec is desired and the clock used is a 100 MHz clock then the MCR value is 100,000.

According to the invention, an MCR service block **22** is coupled to the scheduler **18** and the queue status block **20**. FIG. **2** illustrates the main components of the MCR service block **22**. The MCR service block **22** includes a plurality of timers **24***a*–**24***m*, a corresponding plurality of queue service registers **26***a*–**26***m* and an MCR service register **28**. The number of timers is at least equal to the number of service categories. It will be appreciated, however, that the number of timers may be fewer than the number of queues.

Referring to FIGS. **1** and **2**, the general operation of the apparatus includes the queue status block **20** supplying a queue status signal to the queue service registers **26***a*–**26***m*. The queue status signal is a word indicating which queues are not empty. This word is latched into the queue service registers **26***a*–**26***m* when the timers **24***a*–**24***m* are started. It will be appreciated that the queue status word includes the status of all queues whereas each queue service register refers to a subset of the queues. As the scheduler **18** services queues, it generates a service_q signal which is sent to the multiplexer **14**, the queue service registers **26***a*–**26***m*, and the MCR service register **28**. The service_q signal alters the bits in the queue service registers to indicate which queues have been serviced. For example, when the queue status word is generated a 1 bit is used to indicate a non-empty queue. As queues are serviced, the 1 bits are zeroed. When a timer expires, the queue service register associated with the timer is latched into the MCR service register **28**. This represents a list of "starved queues". The MCR service register then signals the scheduler to service the starved queues.

FIG. **3** illustrates a presently preferred embodiment of the methods of the invention as applied to a multiport device. Starting at **100**, queues and timers are set up at **102**. The queue service registers and the MCR service register are initialized at **104** and all timers are started at **106**. An egress port is selected at **108** and the MCR service register associated with that port is checked at **110**. If the MCR service register is empty, the queues associated with the selected port are checked at **112**. If there is at least one non-empty queue, the queue with highest priority is serviced at **114**. The bit in the queue service register associated with the serviced queue is then reset at **116** to indicate that the queue was serviced. At **118** it is determined whether any of the timers associated with this port have expired. If no timers have expired, the next port is selected at **108** and the process is repeated.

If it is determined at **118** that a timer has expired, the expired timer is restarted at **120**, the queue service register is latched into the MCR service register at **122** and the queue service register is updated at **124**.

If it is determined at **110** that the MCR service register lists unserviced (starved) queues, the starved queues are serviced at **126** and the MCR service register is reset to zero at **128**.

The methods described in FIG. **3** are also illustrated in the previously incorporated appendix and in particular at section 4.3 of the appendix.

There have been described and illustrated herein several embodiments of methods and apparatus for guaranteeing a minimum cell rate for asynchronous transfer mode traffic queues. While particular embodiments of the invention have been described, it is not intended that the invention be limited thereto, as it is intended that the invention be as broad in scope as the art will allow and that the specification be read likewise. For example, while it is preferred that there be at least one queue per service category and at least one timer per service category, it is possible that there be fewer timers, e.g. one timer per MCR class(es) of service. It will therefore be appreciated by those skilled in the art that yet other modifications could be made to the provided invention without deviating from its spirit and scope as so claimed.

What is claimed is:

1. An apparatus for guaranteeing minimum cell rate (MCR) in an asynchronous transfer mode (ATM) device, said apparatus comprising:

a) a first plurality of queues, at least one for each service category;

b) a scheduler coupled to said queues for dequeuing cells from said queues in order of priority;

c) at least one timer associated with at least one of said queues; and

d) preemption means coupled to said at least one timer and to said scheduler for preempting said scheduler, wherein

said preemption means always causes said scheduler to dequeue a cell from said at least one queue associated with said at least one timer whenever said at

least one timer expires if a cell from said at least one queue associated with said at least one timer is not dequeued by said scheduler before said timer expires.

2. An apparatus according to claim **1**, wherein:

said at least one timer includes at least one timer for each class of service.

3. An apparatus according to claim **1**, wherein:

said preemption means includes an MCR service register for indicating which queues are to be serviced when said at least one timer expires.

4. An apparatus according to claim **1**, wherein:

said preemption means includes at least one queue service register for indicating which queues have been serviced.

5. An apparatus according to claim **2**, wherein:

said preemption means includes a queue service register associated with each timer for indicating which queues have been serviced before the timer expires.

6. An apparatus according to claim **2**, wherein:

said preemption means includes an MCR service register for indicating which queues are to be serviced when a timer expires.

7. An apparatus according to claim **4**, wherein:

said preemption means includes an MCR service register for indicating which queues are to be serviced when a timer expires.

8. An apparatus according to claim **5**, wherein:

said preemption means includes an MCR service register for indicating which queues are to be serviced when a timer expires.

9. A method for guaranteeing minimum cell rate (MCR) in an asynchronous transfer mode (ATM) device, said method comprising:

a) establishing at least one queue for each service category;

b) dequeuing cells from the queues in order of priority;

c) establishing at least one timer associated with at least one of said queues; and

d) always dequeuing a cell from the at least one queue associated with the at least one timer whenever the at least one timer expires if no cells have been dequeued from the at least one queue associated with the at least one timer before the timer expires.

10. A method according to claim **9**, wherein:

said step of establishing at least one timer includes establishing at least one timer for each class of service.

11. A method according to claim **9**, further comprising:

e) establishing an MCR service register for indicating which queues are to be serviced when the at least one timer expires.

12. A method according to claim **9**, further comprising:

e) establishing at least one queue service register for indicating which queues have been serviced.

13. A method according to claim **10**, further comprising:

e) establishing a queue service register associated with each timer for indicating which queues have been serviced before the timer expires.

14. A method according to claim **10**, further comprising:

e) establishing an MCR service register for indicating which queues are to be serviced when a timer expires.

15. A method according to claim **11**, further comprising:

f) establishing at least one queue service register for indicating which queues have been serviced.

16. A method according to claim **13**, further comprising:

f) establishing an MCR service register for indicating which queues are to be serviced when a timer expires.

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